Electrothermal Simulation
FLOORS

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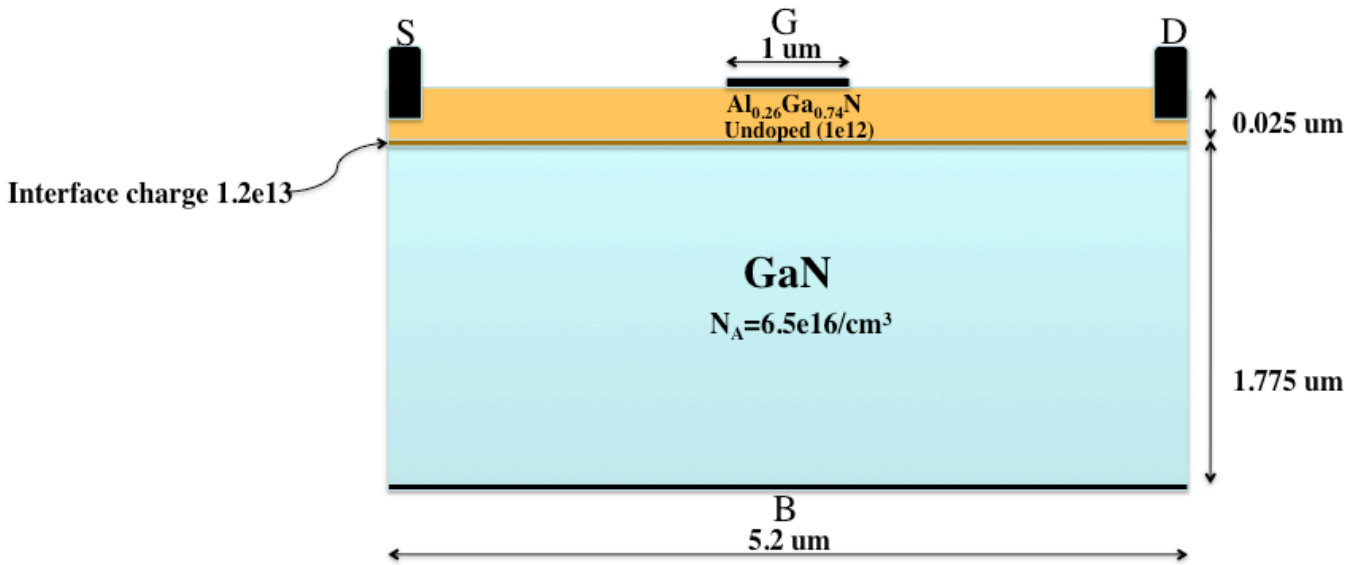
- Overview
  - Progress with AlGaN/GaN structure
  - Base plate temperature variation
  - Development of AFRL structure
  - Collaboration with Materials Characterization group (Ren)

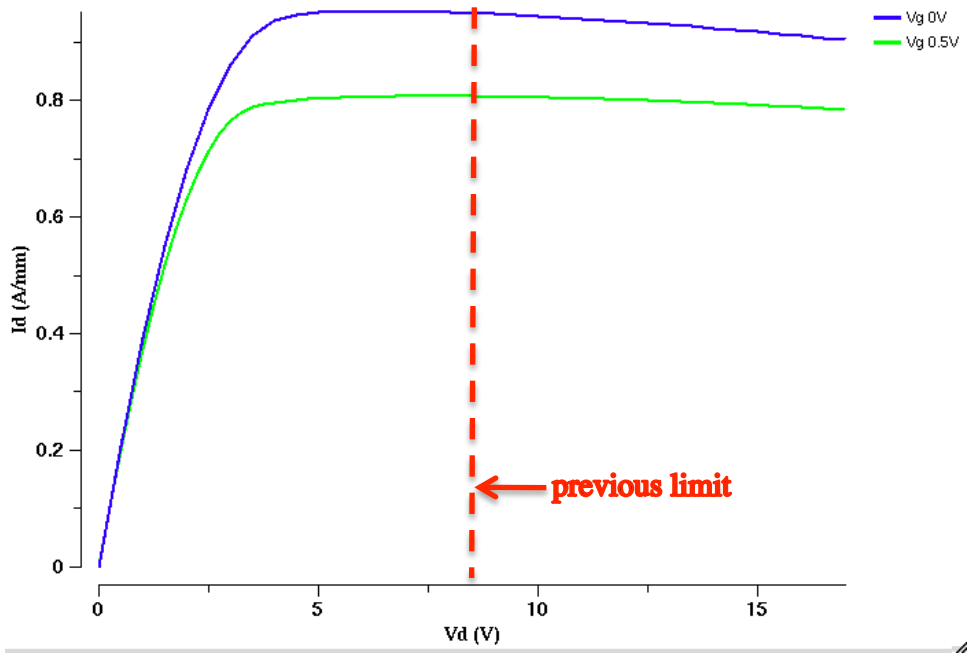
Simple AlGaN/GaN structure



[Not to scale]

- At the last review
  - Material parameter and mobility temperature dependence achieved
  - Bias conditions limited
  - Base plate temperature constant

Developmental Progress in Bias Conditions



- I_D vs. V_D simulations now extend beyond 20 V
  - Grid, mesh, step size changes
- Curve behavior shows mobility model robustness
  - Negative differential resistance (increasing voltage, decreasing current) is a notorious convergence issue
- I_G vs. V_G simulations now extend beyond -30V
- Accelerated lifetime testing simulations can now be done

Base Plate Temperature Variation

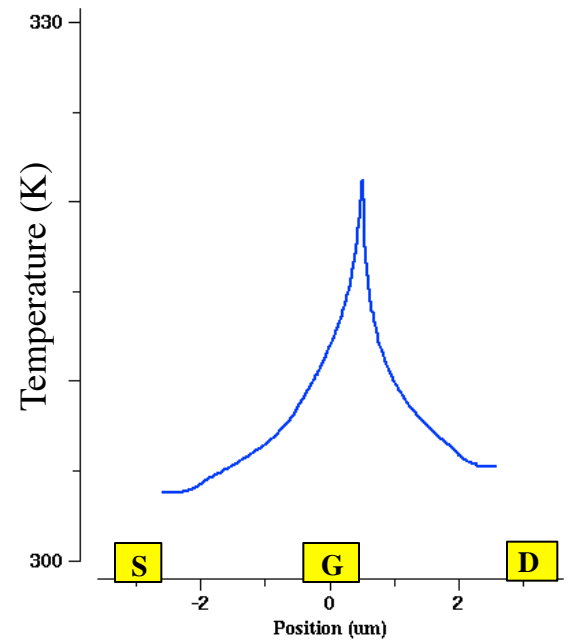
- Variable temperature boundary condition applied to bulk contact:

$$\kappa \frac{\partial T}{\partial N} = h(T_{ext} - T)$$

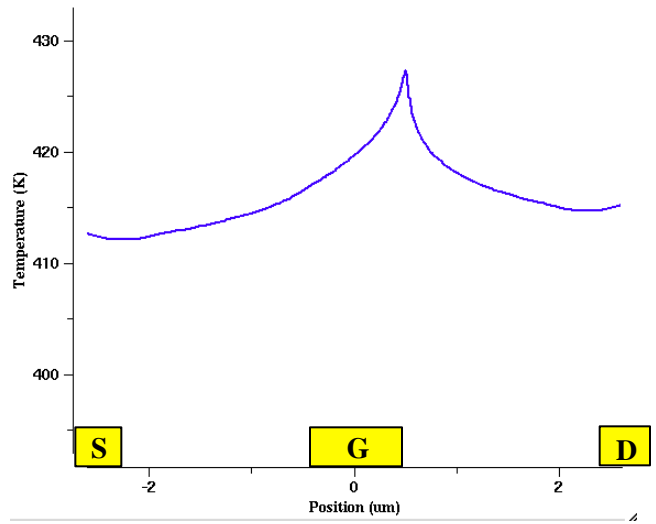
$\kappa \equiv$ thermal conductivity
$h \equiv$ heat transfer coefficient
T_{ext}=Base plate temperature

	GaN	SiC
κ (W/cm•°K)	2.67	1.20
h (W/m²•°K)	12.5	30.0

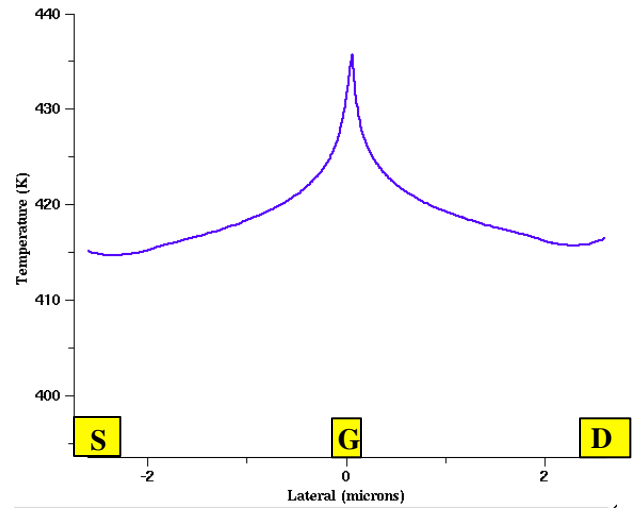
Power 6.2 W/mm



GaN Bulk Contact
Base plate Temp 25 °C

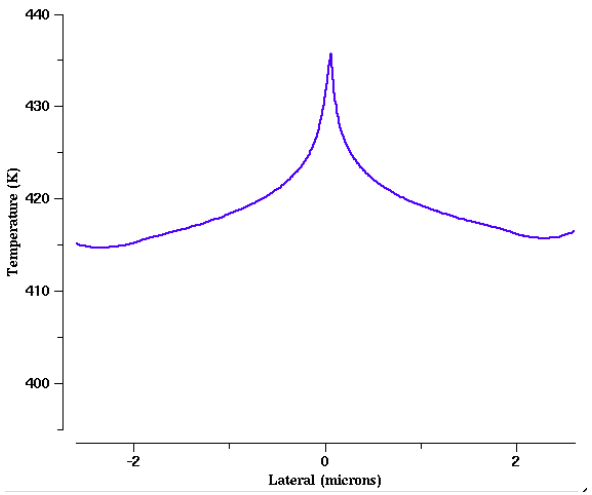


GaN Bulk Contact
Base plate Temp 85 °C

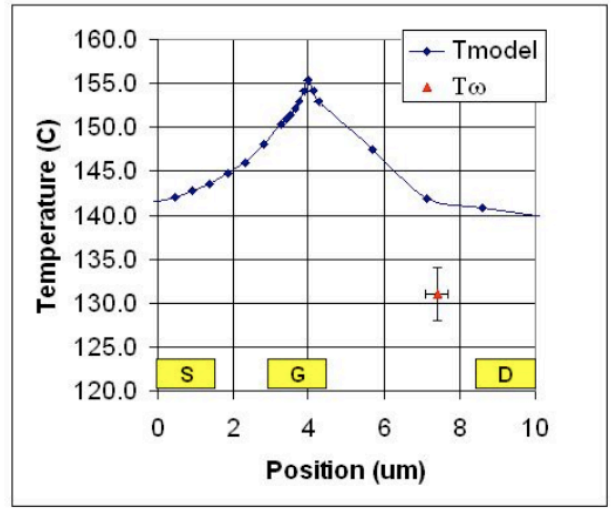


SiC Bulk Contact
Base plate Temp 85 °C

Comparison to Literature



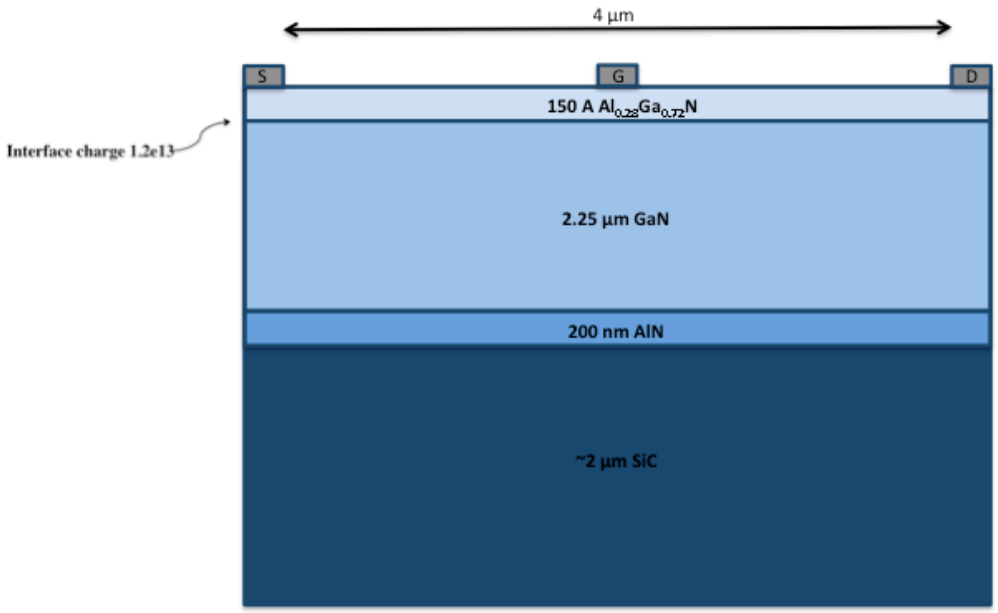
FLOODS
Power 6.2 W/mm
Baseplate Temp 85 °C



Green et. al. Phys. Stat. Sol. (c) **5**, No. 6, (2008)
Power 6.2 W
Baseplate Temp 85 °C

- Good quantitative and qualitative match to literature
  - Position and shape of profiles similar
  - S/D temperature:
    - FLOODS: 142 °C
    - Green et. al.: 141 °C
  - Gate temperature:
    - FLOODS: 163 °C
    - Green et. al.: 156 °C
  - Still different power conditions (W/mm vs. W)
- Future work
  - Curves for power dissipation vs. base plate temperatures
  - Higher base plate temps (200-250 °C) to simulate accelerated lifetime testing

Development of AFRL Structure



- Addition of two new materials to FLOODS:
  - AlN
  - SiC
- Change in
  - gate size
    - 100 nm from 1 um
  - AlGaN composition
    - 28% from 26%
  - Layer thicknesses
- GaN Cap not included

Material Parameters

	AlN	SiC
K_s	8.5	9.6
X (eV)	1.21	3.70
E_g (eV)	6.13+((1.8e^{-3}*T*T)/(1462+T))	3.2-((3.3e-2*T*T)/(1e5+T))
c (J/°K•cm^3)	2.58	2.40
K (W/cm•°K)	2.85	1.20

Mobility Parameters for AFRL Structure

Low Field Mobility Parameters

	AlN	SiC
μ_{min}	297.8	312.1
μ_{max}	683.8	1401.3
α	1.16	0.74
β_1	-1.82	-6.51
β_2	-3.43	-2.31
β_3	3.78	7.07
β_4	0.86	-0.86
N_{ref}	1e17 cm^{-3}	1e17 cm^{-3}

High Field Mobility Parameters

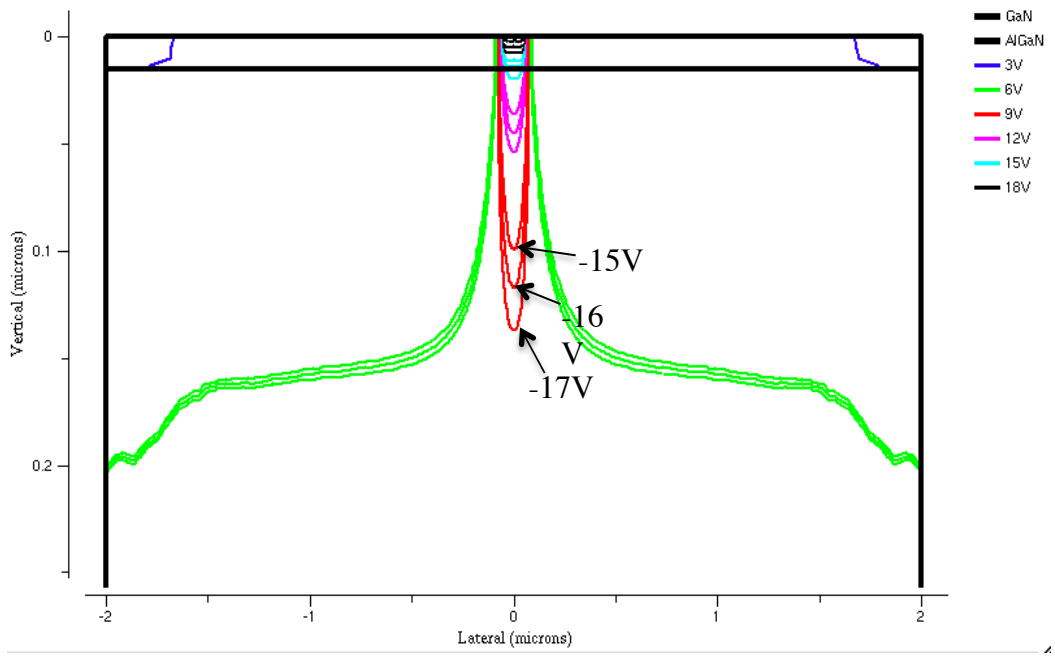
	AlN	SiC
a	8.7253	6.9502
n_1	17.3681	7.8138
n_2	0.8554	0.7897
μ_o	447033.9	245579.4
V_{sat}(cm/s)	2.167e7	2.02e7
Ec (kV/cm)	447.0339	245579.4

Current Capabilities with AFRL Structure

- Temperature dependence
  - All materials use thermal transport equations
  - All materials use temp-dependent mobilities
  - Some materials use temp-dependent N_C, N_V, E_g
  - Reasonable temperature profiles
- I_G vs V_G curves
  - Good performance to V_G=-20V for V_D &V_S=0V
- I_D vs V_D curves
  - Convergence for V_G=0 to -3V while V_D=0 to 8V
  - Curves do not show saturation
    - Working on doping values of layers

Collaboration with Materials Characterization

Device Potential in volts for
Gate size: 100 nm Vg=-15, -16, -17 V Vd, Vs=0 V



Simulation conditions

Gate size	V_G
100 nm	-15V
	-16V
	-17V
125 nm	-21V
	-22V
	-23V
140 nm	-26V
	-27V
	-28V
170 nm	-31V
	-32V
	-33V

- Using AlGaN/GaN layer structure
- Able to provide device potential plots
  - Electric field plots in development

Current and Future Work

- Current work
  - Refining simulations for AFRL structure
  - Adding electric field plotting capabilities
  - Expanding collaborations with materials characterization group
- Future work
  - Simulating changes in piezoelectric component of polarization charges at AlGaN/GaN interface
  - Simulating accelerated lifetime testing